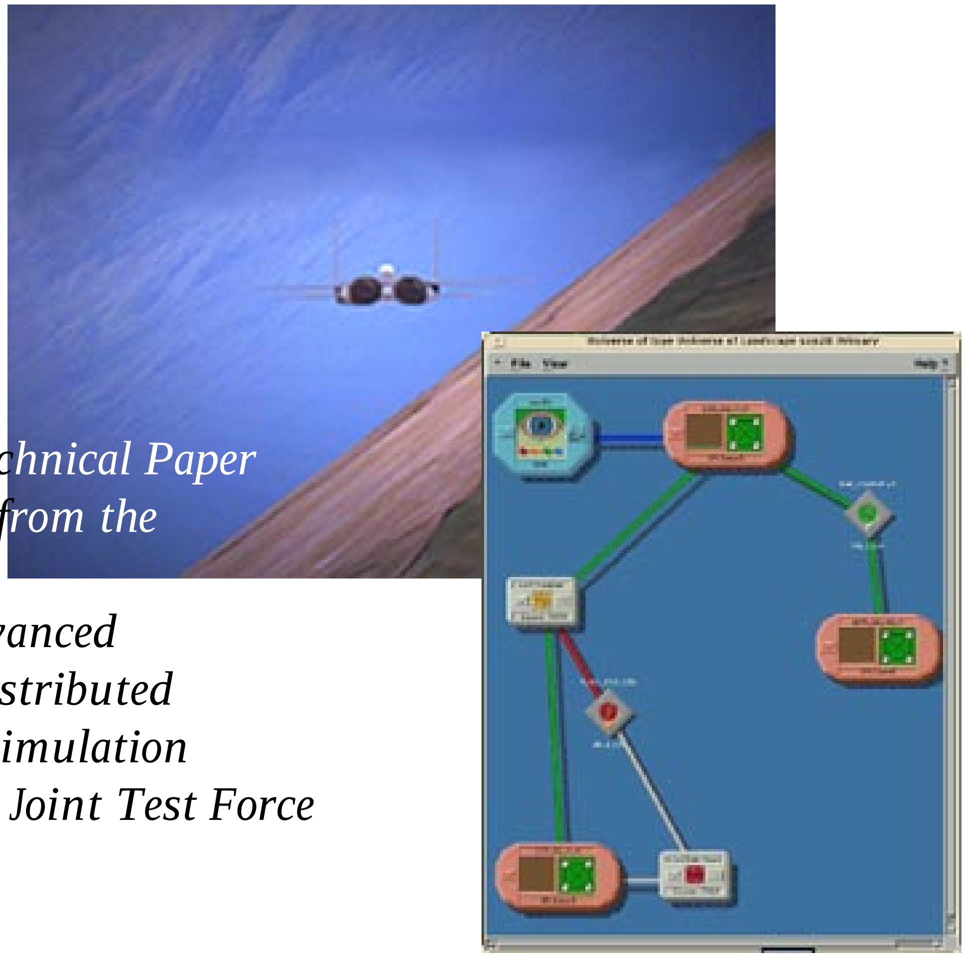
Analysis Tools and Procedures for Distributed Networks



A Technical Paper
from the
Joint
***A**dvanced*
***D**istributed*
***S**imulation*
Joint Test Force

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ABSTRACT

The Joint Advanced Distributed Simulation (JADS) Joint Test Force (JTF) is chartered by the Office of the Secretary of Defense to investigate the utility of Advanced Distributed Simulation (ADS) Technology to Test and Evaluation (T&E). JADS is executing three formal test programs representing slices of the overall T&E spectrum to form its conclusions, linking live test assets, constructive models, and virtual simulations at multiple test facilities and test ranges across the country. Although each test targets different distributed equipment, all three tests have similar requirements for a methodology and tools that support evaluation of cross-country network performance and its impact on data quality. JADS uses a suite of both on-site and remote network monitoring tools to provide insight into distributed network performance before, during, and after test exercises.

Prior to conducting any test exercise, it is important that a baseline analysis of the network's capabilities be performed. The comparison of baseline capabilities to projected network requirements allows identification of network shortcomings so that they can be addressed and provides confidence that distributed equipment will be able to communicate satisfactorily during testing. The baseline characterization of JADS network links includes Bit Error Rate Testing, or BERT, both no-load and loaded link latency testing, PDU (or HLA packet) verification testing, and stress testing.

During JADS test execution, network analysis is an integral part of the test control and monitoring process. Latency, error rates, and data verification continue to be of high interest. In addition, packet rate, bandwidth utilization, link availability, and time synchronization across sites may be monitored real-time. A specific network portion may be monitored continuously if immediate notification of a network outage is necessary. Network monitoring tools provide a remote troubleshooting capability that enables JADS test personnel to identify the problem's exact location and probable cause, should an outage occur.

The evaluation of network performance post-test is no less useful. Statistical analysis of link availability, bandwidth utilized, or other parameters based on data collected during testing helps characterize network usage trends. The detailed understanding of network performance gained through such study can be instrumental in implicating or exonerating the network as the cause of an observed test anomaly or degradation in data quality. Identification and understanding of network shortcomings leads to better definition of network requirements; paving the way for smoother future test events.

A variety of both in-house and commercially available data logging tools, network performance analysis tools, and time synchronization tools, as well as simple protocol analyzers and utilities, provide JADS with the capability to perform network analyses to support these purposes. This paper will discuss these tools and concepts in the context of the second formal JADS test program, the End-To-End (ETE) Test.

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1. INTRODUCTION

The Joint Advanced Distributed Simulation (JADS) Joint Test Force (JTF) is chartered by the Office of the Secretary of Defense to investigate the utility of Advanced Distributed Simulation (ADS) Technology for support of Test and Evaluation (T&E) in three areas:

- Investigate the present utility of ADS for T&E
- Identify the critical constraints, concerns, and methodologies when using ADS for T&E
- Identify the requirements that must be introduced into ADS systems if they are to support a more complete T&E capability in the future

JADS is executing three formal test programs representing slices of the overall T&E spectrum to form its conclusions, linking live test assets, constructive models, and virtual simulations at multiple test facilities and test ranges across the country.

A critical issue that JADS confronts in addressing these issues, and one with broad significance as ADS continues to be employed by the T&E community, is the impact of the communications network on the quality of test data generated and collected. Due to the distributed (networked) nature of ADS, it is possible for network performance to degrade the quality of collected data, and therefore, test results.

JADS JTF formal test programs require a methodology and tools that support evaluation of cross-country network performance and its impact on data quality. A variety of both in-house and commercially available data logging tools, network performance analysis tools, and time synchronization tools, as well as simple protocol analyzers and utilities, provide JADS with the capability to perform network analyses to support these purposes. This paper discusses these tools and concepts in the context of the second formal JADS test program, the End-To-End (ETE) Test, which underwent successful Phase 2 testing from 14 Sep 98 to 2 Oct 98. A previously published JADS paper, entitled "Collection and Analysis of Quality Data in a Distributed Simulation Test Environment," details similar analysis tools and processes employed during the first JADS test effort, the Systems Integration Test (SIT). After further progress is made in evaluating network performance for future ETE test phases and the third JADS test, the Electronic Warfare (EW) test, JADS assessment of the similarities and differences among the tools and processes used during the three tests will be presented to the T&E community.

2. BACKGROUND

2.1 THE END-TO-END (ETE) TEST

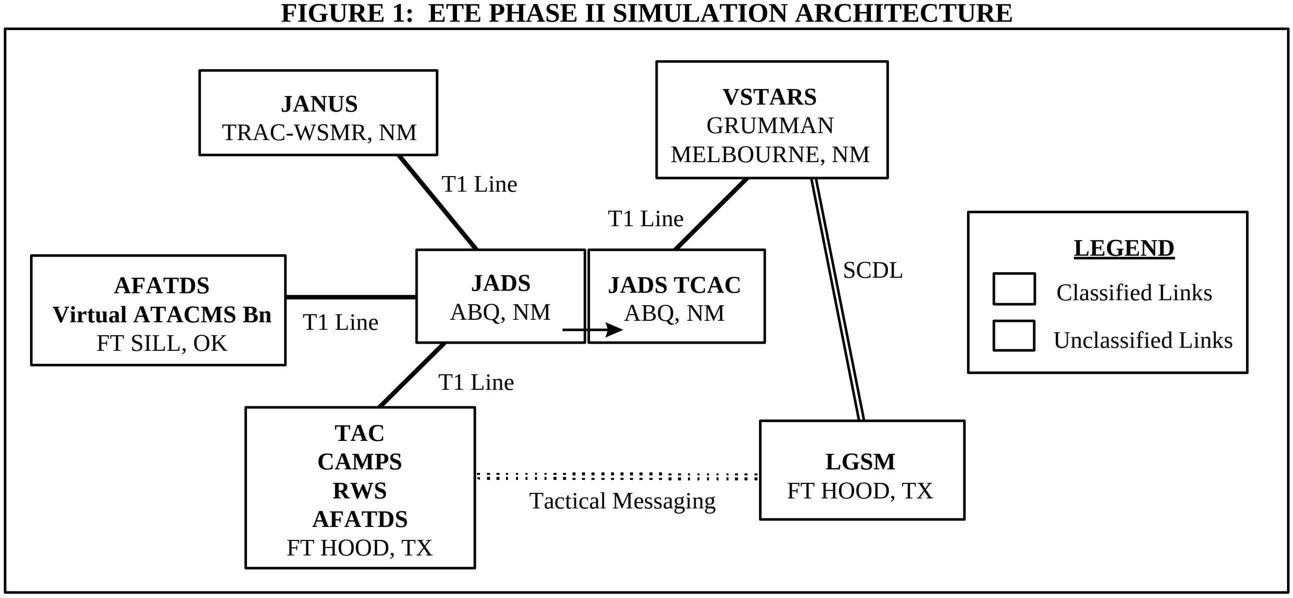
The purpose of the ETE Test is to investigate the utility of using ADS to complement the developmental and operational test and evaluation of a Command, Control, Communications, Computers, and Intelligence (C4I) system. The Joint STARS surveillance system, which provides commanders access to near real-time radar imagery data in support of targeting decisions, was chosen as a representative C4I platform. Previous C4I system testing has exhibited shortfalls in providing adequate numbers of forces, friendly or enemy, to realistically portray an expected operational environment. The basic concept behind the ETE Test is to augment the Joint STARS environment with a virtual environment created by thousands of simulated entities, or targets. The virtual environment is imaged by a simulation of the radar systems contained within the Joint STARS E-8C aircraft mixed with real radar returns to provide a robust operational environment.

The ETE is a four-phase test. The equipment linked in the first two phases consists primarily of constructive and virtual simulations which are representative of test assets available during DT&E and early OT&E scenarios; the latter two ETE test phases are enhanced by the inclusion of a live E-8C aircraft and open-air testing.

2.2 ETE PHASE II SIMULATION ARCHITECTURE

The ETE Joint STARS simulation is called the Virtual Surveillance Target Attack Radar System (VSTARS). During Phase 2, this simulation is operated from a Grumman facility in Melbourne, Florida. Information representing the status of each simulated entity, or target, is transmitted to VSTARS through the use of a slightly modified Distributed Interactive Simulation (DIS) Entity State Protocol Data Unit (ESPDU). ESPDU status information is used to update the data base that generates VSTARS virtual radar images. The ESPDUs are transmitted from Army Training and Doctrine Command's Analysis Command (TRAC) at White Sands Missile Range (WSMR), New Mexico, where they are generated by an Army constructive simulation known as JANUS. An interface was developed by TRAC-WSMR to convert JANUS simulated target entity output to ESPDU form. The ESPDUs are transmitted to the Grumman site via the JADS Test Control and Analysis Center (TCAC) in Albuquerque, NM. The simulation architecture for the ETE Phase 2 Test is shown in Figure 1.

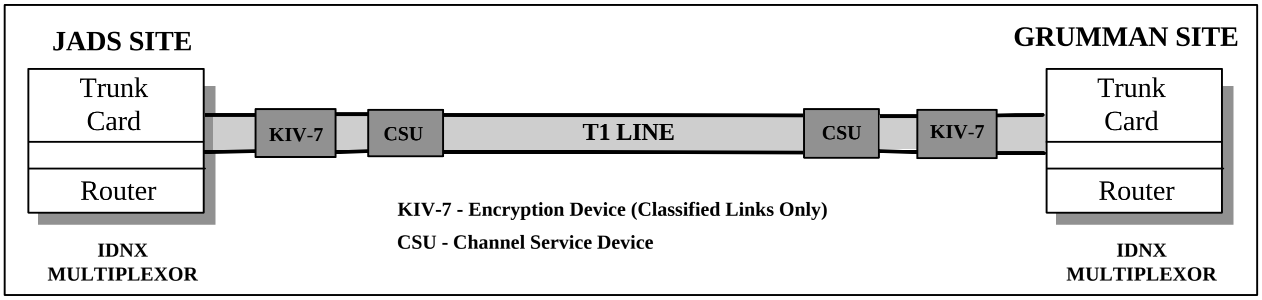
FIGURE 1: ETE PHASE II SIMULATION ARCHITECTURE



Network nodes representing live elements of the Army's artillery command and control process and other appropriate C4ISR major ground systems are included in the ETE simulation architecture, including the Army's Light Ground Station Module (LGSM) operators at Ft Hood, Texas, and a simulation of the Army's Advanced Tactical Missile System (ATACMS) at Ft Sill, Oklahoma, called TAFSM. A Surveillance Control Data Link (SCDL) is utilized to transmit data traffic between the E-8C operators at Grumman and the LGSM operators at Ft Hood, representing the line-of-sight connection that would exist in the real field of operations between the two systems. The LGSM operators provide intelligence data on entity movement to the Tactical Analysis Cell (TAC) Remote Workstation (RWS) via the Compartmented All-Source Analysis System (ASAS) Message Processing System (CAMPS). TAC Advanced Field Artillery Tactical Data System (AFATDS) operators send fire mission requests to the Ft Sill AFATDS as inputs to the TAFSM simulation. DIS Fire and Detonate PDUs are generated by TAFSM to represent the performance characteristics of the ATACMS. The state of VSTARS target entities is updated by the JANUS simulation at WSMR to close the simulation loop.

A representative ETE network segment, depicted in Figure 2, shows the equipment used to link distributed ETE nodes, and may be helpful in visualizing the JADS concepts and network performance monitoring tools discussed in the following paragraphs.

FIGURE 2: ETE PHASE II TEST NETWORK LINK ARCHITECTURE



3. DISCUSSION

The ability to understand and quantify the impact of network performance on the quality of data collected during an ADS test is a critical factor in JADS' ability to provide meaningful insight into the overall utility of ADS for T&E. Measures of performance for the ETE Phase 2 test are established to support attainment of this understanding by answering specific questions such as, "What is the maximum latency between ADS nodes?", "What percentage of planned ADS trials must be delayed or canceled due to network problems?", and "What percentage of available bandwidth is utilized?" These and similar questions must be answered by studying and measuring network performance characteristics prior to, during, and following test events.

3.1 NETWORK PERFORMANCE CHARACTERISTICS

There are certainly many ways of evaluating the performance of a wide-area network. JADS testers have focused on studying those characteristics that provide a well-rounded picture of how the network is performing in support of the data needs associated with distributed testing. If monitored performance values meet expected thresholds and remain within acceptable boundaries, it is likely that data collection and integrity problems will not arise. On the other hand, if monitored values cross expected thresholds or exceed acceptable boundaries, it is possible that network problems could result in loss of simulation integrity, data loss, or collection of inaccurate system under test data. The following discussion is intended to clarify the meaning and usage of each performance characteristic as it relates to monitoring network performance for JADS ETE Phase 2 testing.

LATENCY. JADS uses latency as a measure of the time to move data from a source to a destination. The exact meaning differs slightly depending on the end equipment point at which the measurement is made. For ETE testing, latency is measured using a time stamp recorded as the data is logged at the destination. This value is compared to the simulation data creation time, if known, or the time stamp recorded as the data is logged at the source. Latency in a network can be caused by the circuit path; routers, hubs, and other network equipment; and processes within the computers and simulation systems themselves.

TIME SYNCHRONIZATION. JADS analysis of the impact of distribution on simulation integrity and data collection is based on the analysis of latency between various nodes; the foundation of this analysis is accurate time synchronization over the cross-country network's simulation machines and data logging devices. The JADS accuracy requirement for synchronization of machine clocks and time stamping is 1 millisecond.

LOAD (BANDWIDTH UTILIZED). The concept of load, or the ratio of bandwidth utilized during data transmission to the capacity (maximum data rate) of a given circuit, is key to understanding the amount of data traffic, or throughput, that can successfully be sent over a given link. If experienced load is close to capacity, data may not be transmitted in the timely and accurate manner required to ensure simulation integrity.

PACKET RATE. Monitoring the actual rate at which packets are transmitted over network links provides insight into the type, amount, and quality of data that is being input and output from specific nodes. Values outside of expected ranges may point to network problems.

LINK AVAILABILITY AND RELIABILITY. These two concepts are closely related in their importance to understanding the tester's ability to use the network to pass simulation data traffic when needed. The focus of availability is on readiness, while the focus of reliability is on continuity. A network that is susceptible to interference from events outside the tester's control may not be available when a test event is scheduled. Such events may include equipment failures, long haul communications problems, or competing demands for bandwidth. An unreliable network link may experience frequent problems that result in failure to pass needed traffic in the middle of a test event. Network failures during a test event may degrade the quality of system under test data, cause amounts of simulation data to be lost completely, and even render entire test events worthless.

3.2 NETWORK MONITORING TOOLS AND TECHNIQUES

Since its inception, JADS has explored a variety of commercially developed products, as well as developed a substantial number of procedures and products in-house, to both characterize distributed networks and provide insight into their performance. An overview of the processes and tools used by the JADS team to support the ETE Phase 2 exercise are discussed below, with examples, according to their utility in supporting pre-test, during, and post-test network characterization activity.

3.2.1 NETWORK PLANNING & DESIGN (PRE-TEST)

The development of the ETE Phase 2 cross-country network began early in the test's planning stage with an evaluation of requirements. Test team experts, familiar with both ADS concepts and the ETE Phase 2 simulation's equipment, operators, and scenarios, developed requirements for network latency, bandwidth, maximum error rate, availability, security, timing accuracy, and others, based on their understanding of the systems that would be linked together and the type, number, and size of data packets that would be passed along the various segments. For instance, an understanding of the circular error probable (CEP) of the E-8C (Joint STARS) radar imposed a maximum latency requirement on certain links of the network in order that radar screen activity look realistic to operators. An understanding of the rate at which JANUS, the primary PDU producer, would generate data, imposed a minimum data broadcast rate of 100 data packets per second. This expected data rate, or EDR, was used, along with an understanding of the size of the PDUs and other data traffic that would travel to and from each site, to calculate a network bandwidth requirement. The JADS Network & Engineering (N&E) team worked to provide a feasible technical solution by balancing these requirements with hardware performance and costs.

3.2.2 NETWORK BASELINE CHARACTERIZATION (PRE-TEST)

Once a network solution was devised and implemented by the N&E team, network tests were executed to determine the extent of the network's capability in terms of the performance constructs discussed above. These tests were performed in order to characterize reliability, latency, and packet rate characteristics, determining the boundaries within which the network can satisfactorily operate to maintain simulation and data integrity.

BIT ERROR RATE TESTING (BERT). As a first step, a Bit Error Rate Test (BERT) was performed on every communications circuit to verify equipment operation and point-to-point transmission quality. A random test pattern was used to simulate the effects of live traffic; deviations from the pattern at the receiving end being counted as errors. The Bit Error Rate is the ratio of the number of bit errors to the number of bits transmitted. The BERT is a valuable tool in determining whether the link is performing reliably within specifications, and it can be utilized upon installation or at any later time to identify a performance degradation during testing.

LINK CHARACTERIZATION. Further network characterization involved baselining the performance of a particular link. A variety of network and engineering tests were used to calculate round-trip latencies and determine the maximum rate at which PDUs can be sent before data drop-outs occur. A description of, and sample results from, each test used to gather this data as part of the ETE network characterization study in Dec '97, follow:

The No Load Latency Test involved using the UNIX *ping* utility to send a volley of 64 byte *pings* across a link and analyzing the round trip latency values. Example results, using 32 *pings*, for the ETE classified TCAC to Grumman link are shown in Table 1.

TABLE 1: LINK LATENCY TEST - NO LOAD					
			Round Trip Time (ms)		
Source	Destination	# Pings	Minimum	Average	Maximum
JADS	GRUMMAN	32	57	57	71

The Loaded Latency Test consisted of transmitting 144 byte (loaded) *pings* at several different rates to determine round trip link latencies. Example results for the ETE classified TCAC to Grumman link are shown in Table 2.

TABLE 2: LINK LATENCY TEST - LOADED						
				Round Trip Time (ms)		
Source	Destination	Frequency (sec)	# Pings	Minimum	Average	Maximum
JADS	GRUMMAN	.01	320	58	60	163
JADS	GRUMMAN	.005	640	58	58	61
JADS	GRUMMAN	.0025	1280	58	58	124
JADS	GRUMMAN	.00125	2560	58	58	167

The PDU Verification Test was aimed at determining network reliability in delivering data packets sent at a particular data transmission rate, in this case, 100 packets per second, the expected data rate over the TCAC to Grumman link during ETE testing. Files recorded by data logging tools, discussed later in this paper, residing at both sending and receiving nodes were compared to determine results. An example is presented in Table 3.

TABLE 3: PDU VERIFICATION TEST					
Source	Destinatio n	# PDUs Transmitted	# PDUs Received	# PDUs Out of Order	# PDUs > 1 sec
JADS	GRUMMAN	11859	11859	0	0

The Stress Test supported characterization of latency, reliability, and bandwidth constructs should the data transmission rate exceed the EDR. For the ETE classified TCAC to Grumman link, the PDU rate was gradually increased from the EDR of 100 packets per second to five times that rate. Bandwidth information was captured by a commercial analysis package discussed later in this paper. Example results are shown in Table 4.

TABLE 4: STRESS TEST						
Packet Rate	# PDUs	# PDUs	Round Trip Time (ms)			Bandwidth
(PDUS/sec)	Transmitted	Received	Minimum	Average	Maximum	Utilized (%)
100	11859	11859	60	61	120	10
200	11859	11858	59	68	90	21
300	11859	11853	59	64	90	28
400	11859	11847	57	79	210	40
500	11859	10492	57	256	840	45

This characterization study shed light on the packet rate and size boundaries within which ETE simulation activities can occur before degradation in network performance and data quality is experienced. Latency, data reliability, and utilized bandwidth results should be comparable to values recorded during testing and post-test analysis of these same constructs.

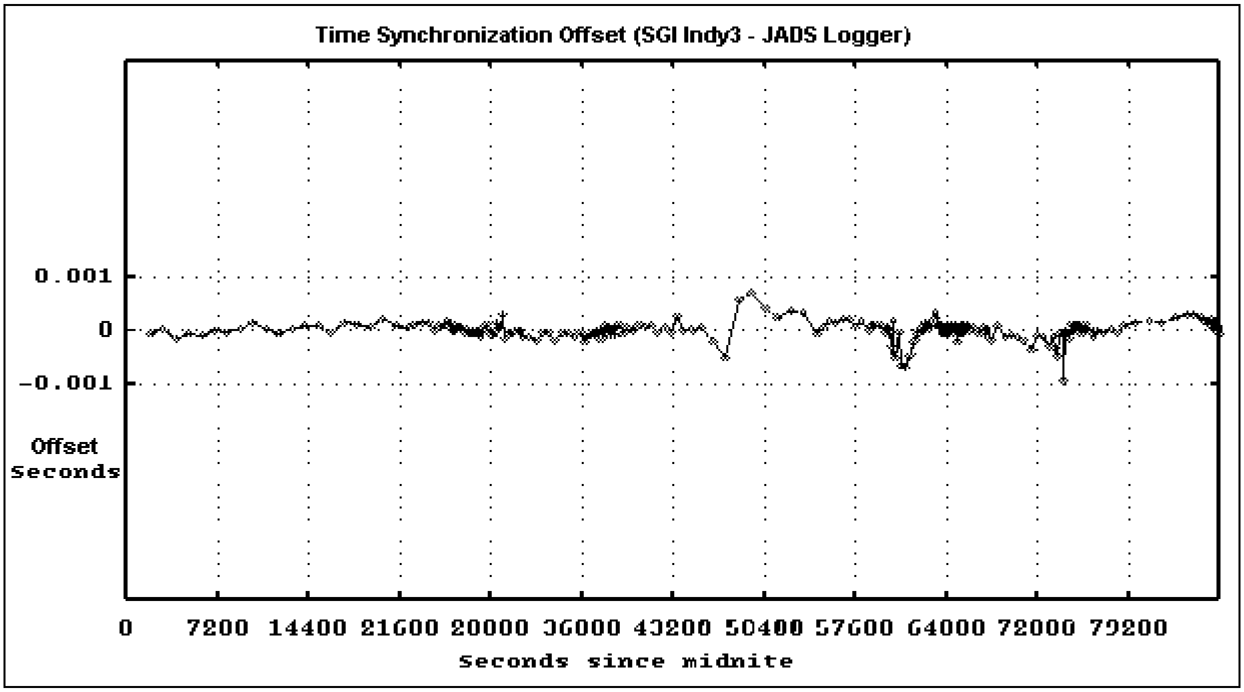
3.2.3 REAL-TIME NETWORK MONITORING TOOLS (DURING TEST):

A combination of in-house tools and commercially developed software products provide JADS with a real-time capability to assess network performance and evaluate the integrity of data as it is being collected during ETE testing. The value of real-time insight is in support of distributed test monitoring and control. Since all aspects of the test may not be readily visible to operators and controllers at sites separated by thousands of miles, it is these tools that allow knowledge about test events and associated data to be gained essentially as the events happen. If there is a problem, or some reason to stop and redo a particular test event, it is obvious almost immediately to test controllers.

DATA LOGGING. Although a variety of data logging products have been tested by JADS, a Distributed Simulation Technology, Incorporated (DiSTI) product modified in-house was deemed most appropriate for use during ETE Phase 2. The JADS logger is employed at each distributed ETE site to which PDUs are broadcast. A counter indicates the number of PDUs received and shows immediately if PDU traffic is halted for some reason. As each day's testing occurs, a log file is created at each site to capture and time stamp all data traffic sent or received. The logger files from all sites are sent to JADS for post-test analysis. An interesting feature of the JADS Logger is that it is command line operated and can be manipulated via remote "login" over the network. Test controllers can remotely start and stop the logging process without remaining logged on and utilizing added bandwidth. Another facet that makes the JADS Logger such a valuable tool is the separation of its time-stamping and data recording processes. To ensure absolute accuracy, the time-stamping process has priority; data is buffered and written to file when processing time permits. The logger was created without a graphical front-end so that processing time could be dedicated to accurate data recording.

TIME SYNCHRONIZATION. There are currently multiple hardware products and software applications commercially available for synchronizing simulation time. At the time JADS N&E team was looking for a synchronization solution to satisfy ETE test needs, Global Positioning System (GPS) or Inter-Range Instrumentation Group standard time signal cards (IRIG-B) compatible with the ETE architecture's Silicon Graphics Incorporated (SGI) Indy workstations were not available. The team developed a software solution based on the Network Timing Protocol (NTP), using XNTP, a free NTP tool developed at the University of Delaware. XNTP uses a UNIX daemon, xntpd, to synchronize a local workstation clock to a time source; JADS uses the time signal from a GPS receiver connected to the workstation's serial port. The daemon software adjusts the local clock as necessary; all other network workstations request and receive time updates every 64 seconds. Changes are applied gradually so that time stamps in logged data remain sequential and time never appears to go backward. The software continually generates basic statistics on client and server nodes to indicate how well the clocks are staying synchronized. These results can be graphically portrayed as the statistics are generated to allow visual assessment of the time synchronization for any client machine. Figure 3 displays the time offset for a 24 hour period during ETE testing; the client machine remained synchronized within 1 ms over the entire duration.

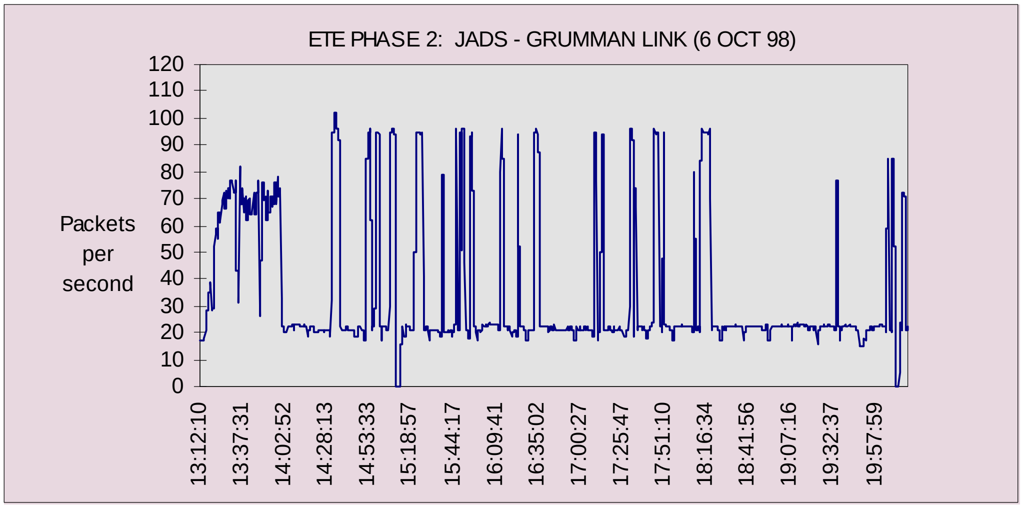
FIGURE 3: TIME SYNCHRONIZATION OFFSET PLOT



NETWORK HEALTH AND STATUS. During ETE test events, JADS uses an SGI product called *NETVISUALYZER* to examine network traffic. This product is actually a suite of tools that can be used during network setup or during testing to ensure that network equipment is configured properly, nodes are talking to each other as intended, and that extraneous network traffic is identified and minimized. Remote Data Stations, located on each wide area network segment, collect data and send it to a central Display Station, where the information is processed by the individual analysis tools and displayed. The additional network load caused by active data collection over the network was found to be negligible for ETE testing. One of the *NETVISUALYZER* tools provides the capability to graphically display network patterns across the entire ETE network. Traffic flow between specific hosts at each site and between sites is shown real-time, enabling test controllers to quickly realize if link availability between sites is compromised. The ability to monitor current packet rate and load at the local area network (LAN) level, a valuable asset in evaluating tactical system or simulation activity at an individual site, is offered by another piece of the *NETVISUALYZER* tool set.

REAL-TIME NETWORK TRAFFIC ANALYSIS. *SPECTRUM*, a network analysis package developed by Cabletron Systems, provides a real-time capability for network traffic monitoring, presenting current packet rate and load information, as well as packet error and discard rate information, for network equipment. The package also provides an Alarm Manager, with simple diagnostic capability, that is valuable in the detection and troubleshooting of network outages. *SPECTRUM* utilizes the Simple Network Management Protocol (SNMP) to periodically query network devices and displays requested information on-screen in table and graph format. The *SPECTRUM* operator can tailor the destination, frequency, and content of the queries to provide the desired level of insight into a particular network portion or piece of equipment. Like *NETVISUALYZER*, *SPECTRUM* queries for data do create network traffic, although not of an appreciable quantity to be noticed in relation to the ETE test traffic. Typically, a five second polling frequency was used to monitor ETE equipment, a value chosen so that short duration problem events would not be missed. Multiple databases store *SPECTRUM's* event log and query results for later analysis. Figure 4 shows packet rate monitored across one ETE network link. The occurrences of packet drops to zero correlate to short duration network outages.

FIGURE 4: SPECTRUM LINK PACKET RATE PLOT



REAL-TIME LINK AVAILABILITY MONITOR. There are numerous ways JADS personnel gain insight into the availability of a particular link. For instance, some of the more complex tools discussed in this paper offer alternatives for monitoring link availability, in addition to the primary purpose for which JADS employs them. In particular, a sudden drop in packet rate picked up by Cabletron's *SPECTRUM*, or an altered data traffic pattern on one of the SGI *NETVISUALYZER* graphs may indicate a network link problem. However, these tools necessarily create additional network traffic with data queries; changing the very nature of the network traffic as they are monitoring it. Taking advantage of the capabilities of simpler tools is one answer to the trade-off between intrusive monitoring and the need for insight into performance. One non-intrusive solution makes use of the self-diagnostic capabilities of the network equipment. For ETE testing, a line printer in the test monitoring and control (TCAC) facility is set up to print diagnostic messages directly from the IDNX multiplexor. The sound of the printer in motion draws immediate attention to a potential equipment outage, without intrusive querying. JADS programmers coded another simple tool, based on the UNIX *ping* utility, that allows ETE test controllers to quickly verify link availability with a glance at one screen. It is affectionately referred to as the "stoplight" tool, since it presents a small green, yellow, or red on-screen graphic for each monitored link, based on the link's current status.

2-D AND 3-D VIEWERS. JADS has explored the capabilities of several different two and three dimensional viewers. The appropriate tool for any particular test event is one that meets the needs of the test controllers in providing a real-time ability to see any entity as it is positioned in space. The JANUS Plan View Display (PVD), a two-dimensional tool, is used during ETE test scenarios for viewing the entire battle scenario as it unfolds. As PDUs are received, simulation entity positions are updated on digital terrain. Due to the enormity of the terrain in comparison to the amount of entity movement, the information provided by the JANUS PVD for ETE testing is not exceptional. In many cases, however, the viewer can be an invaluable tool for bringing together distributed pieces of test action and displaying them as one big picture where they can be evaluated for operational realism and validity. Ideally, problems with virtually all aspects of a distributed simulation, including the network, can be identified through the use of an appropriate viewer.

3.2.4 NETWORK PERFORMANCE DATA ANALYSIS (POST-TEST):

Although much in the way of instilling confidence in collected simulation data is accomplished by closely monitoring the test while it is occurring, even more can be done post-test to ensure that network performance did not degrade or negatively impact collected data in any way, or, if there are indications that it did, to ascertain where and to what extent the data might be corrupted. Again, both in-house and commercially developed products are employed, with focus ranging from providing a general feel about the quality of data immediately following a test event to a more prolonged and detailed assessment of the performance of a particular network link and the associated impact on specific simulation data.

JADS TOOLBOX. The JADS Toolbox contains a variety of in-house developed software tools designed to assess network performance using the logged data files created at each site. The preponderance of these are simple programs, coded in C++, and run in a UNIX environment on an SGI platform. They are used to support characterization of network performance for the array of network performance constructs discussed above, i.e., latency, reliability, packet rate, and time synchronization. Results are compared to baseline, or expected, network characteristics. Specific anomalies, if found, are correlated to raw data files, so that a more detailed evaluation of data integrity can be accomplished.

- BASIC LOG FILE TOOLS. JADS analysts use a few very basic tools to ensure that the data log files from each site are complete, since visual assessment of the binary data format would be both extremely difficult and time consuming. Tools create easily readable summaries of the information contained in a designated log file, including total number of entities, list of entities by number, total simulation time logged, and total number of PDUs logged. Reported values are compared against the numbers expected from a successful simulation event. More specific summary information can be ascertained by filtering on PDU type or source. Example ETE Phase 2 tool output is shown in Table 5, summarizing the number of PDUs of each type received from each other site.

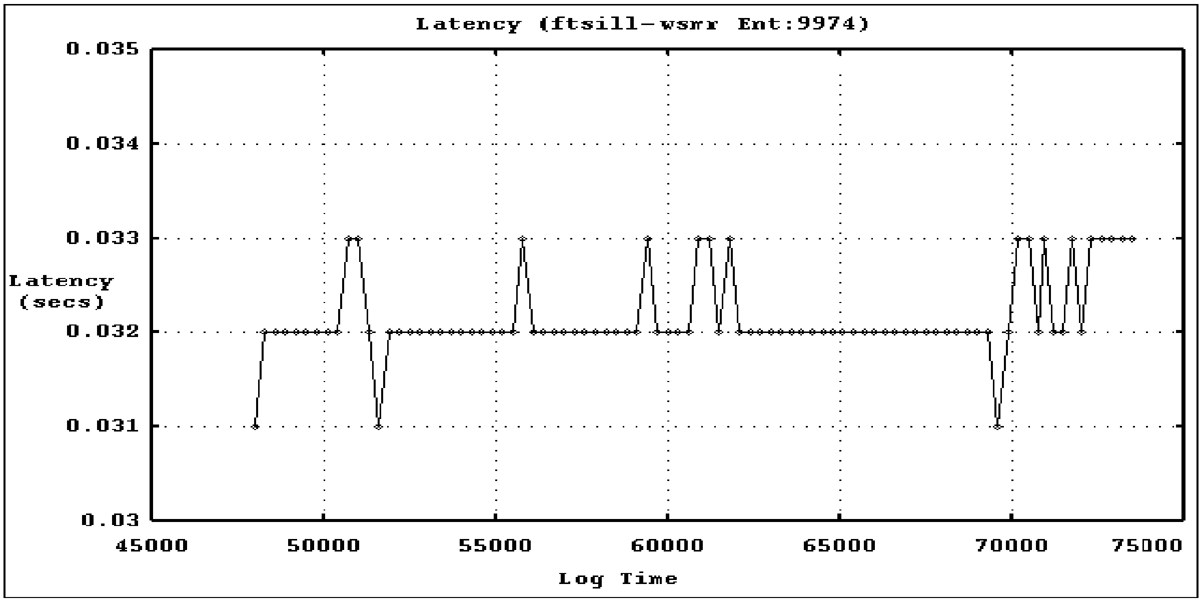
TABLE 5: NUMBER OF PDUS RECEIVED BY SITE - GRUMMAN

SOURCE SITE	ENTITY STATE PDUS	FIRE PDUS	DETONATE PDUS	XMITTER PDUS	SIGNAL PDUS	TOTAL
WSMR	82907	0	0	0	0	82907
FT SILL	2742	58	58	2280	396	5534
TOTAL	85649	58	58	2280	396	88441

- QUICK LOOK TOOLS. "Quick Look" refers to a series of simple programs that are designed to be used quickly after test in order to provide a general gauge of network performance. For the ETE Phase 2 test, these tools are run as soon as the logger files are collected from a single day's test events. The focus of these tools is on latency and PDU performance. Two types of network latency information are gained by running these tools. One is logger to logger latency, gained by comparing the log time stamps for each PDU across different source log files, the other is latency from creation time to any site, determined by comparing PDU time stamps from a particular site's log file to the PDU creation time contained within the PDU itself.   These tools can be run for a particular entity of interest or for all simulation entities. Tools aimed at measuring PDU performance offer a different type of insight, through identification of duplicate, out of order, extremely latent, or even missing, PDUS. Through comparison of the data log files at different sites, it is possible to identify every single PDU that doesn't make it to its destination, information which may be invaluable in correlating odd simulation behaviors or discrepancies to network problems.

- PLOTTING TOOL. Plots created from data log files or from the output of other tools are extremely valuable for their capability to portray information about a particular network performance characteristic at a glance. For instance, plots of output from the time synchronization software are able to quickly show how closely the time on any particular site's equipment corresponds to the simulation time server over the duration of the simulation. Average and extreme latency values across all test PDUs can be gleaned from a single plot, allowing quick identification of those values that exceed expected or allowable thresholds. Figure 5 shows site-to-site latency output for an individual entity during one ETE test event. The consistency of the entity's latency values within an expected range from 31 ms to 33 ms (i.e., site-to-site latency characterized using network *ping* utility is approximately 31 ms) corresponds to appropriate, or expected, entity behavior during the simulation.

FIGURE 5: INDIVIDUAL ENTITY LATENCY (FT SILL TO WSMR)



NETWORK TRAFFIC ANALYSIS. As mentioned earlier, JADS utilizes the Cabletron Systems *SPECTRUM* tool to capture network traffic information through periodic polling and stores the information to database. Post-test, this data is extracted from the database in text format and scrutinized using a spreadsheet or statistical analysis package. Spikes and gullies in graphs of packet rate, error rate, discard rate, and load over the duration of each test event quickly point out inconsistencies in the amount of data collected and can be correlated to known network outages or other simulation problems. Average, minimum, and maximum values are calculated for comparison to expected thresholds and boundaries for network performance parameters. Any unusual trends can be further researched to rule out a potential negative impact on data quality. An ETE link traffic summary, created from *SPECTRUM* data, is shown in Table 6 as an example of the tool's utility. The seemingly inconsistent maximum packet rate value experienced on the first test day prompted analysts to look for unusual simulation behavior. The extreme corresponds to the time period immediately following a freeze of the JANUS simulation, during which additional PDUs were generated and distributed for every system entity in order to update the status of the scenario for all nodes.

TABLE 6: LINK TRAFFIC SUMMARY (JADS - GRUMMAN LINK)

Test Date	Time Test Start	Time Test Stop	Packet Rate (sec)			Average Load (%)
			Minimum	Average	Maximum	
30 SEP 98	13:17	20:26	7.0	18.07	120.0	.63
1 OCT 98	13:40	21:42	6.0	17.99	37.0	.54
2 OCT 98	13:11	20:28	8.0	18.0	33.0	.53
5 OCT 98	13:09	20:17	11.0	16.93	34.0	.33
6 OCT 98	13:12	20:18	9.0	18.60	34.0	.87

4. CONCLUSIONS

Understanding the impact of network performance on the quality of data collected is a critical factor in determining the overall utility of ADS for T&E. JADS seeks to attain this understanding by quantifying network performance for constructs such as latency, time synchronization, bandwidth utilization, and availability. Network characterization pre-test, monitoring during test, and post-test comparison to expected thresholds and boundaries are all important aspects of this evaluation. During the recent ETE Phase 2 test effort, JADS personnel utilized numerous commercially developed products to study network performance. In addition, a number of tools and techniques were developed in-house to provide insight into specific performance issues. Some tools, typically those able to show data in plot or graph format, were extremely beneficial for providing a quick look at a certain parameter, allowing quick comparison to expected baselines and giving testers confidence in simulation integrity. Other tools provide the raw data for more intensive analysis that is instrumental in identifying corrupt or missing data.

Through future phases of testing, JADS will continue to develop a knowledge of the tools and techniques needed for evaluating the performance of wide-area networks in support of distributed testing data needs. An understanding of the importance of studying network performance to ensure collection of quality system under test data, as well as a description of tools and procedures developed or studied by JADS to support that purpose will be an important part of the JADS legacy to the T&E community.